# Appendix C

Engineering Geologic and Erosion Control Study
2002

# ENGINEERING GEOLOGIC AND EROSION CONTROL STUDY OF THE POCKET CANYON THP

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Job: JB-POCKET-282

**SUBJECT: ENGINEERING GEOLOGIC AND EROSION CONTROL STUDY: POCKET CANYON THP**

| | |
|---|---|
| PROPERTY: | Benbow Vineyard |
| | APN 085-140-001 and 002 |
| COUNTY: | Sonoma |
| QUAD: | Camp Meeker |
| WATERSHED: | Pocket Canyon Creek, tributary to the Russian River |

## INTRODUCTION

This report summarizes the findings of our Engineering Geologic and Erosion Control study of the above referenced Timber Harvest Plan (THP) and vineyard conversion. The proposed 185-acre THP is located on gently sloping ridge tops with moderate to steep hillsides within Pocket Canyon, about 2 miles southeast of Guerneville, CA (Figure 1).

The Noel Heights subdivision, located on the east side of the canyon and opposite of the THP, obtains its domestic water from a shallow well located within Pocket Canyon immediately downstream of the proposed THP. It is my understanding that the community has raised concerns over the potential impact the proposed timber harvest and vineyard conversion may have on their water supply. Considering the nature and potential sensitivity of the water system to increased turbidity, CDF has requested a detailed sediment source assessment of the proposed project prior to plan submittal (letter dated September 28, 2001).

The purpose of this study was to evaluate the geologic implications of the proposed harvest and vineyard conversion (hereafter referred to as the Project) with respect to hydrologic changes in water yield and runoff, sediment delivery and increased turbidity to watercourses. The principal geologic concern is the potential impact of the harvest on the Noel Heights water system. Secondary concerns are increased erosion and sediment delivery to the Pocket Canyon and the Russian River, a

USEPA 303 (d) listed waterbody.

We worked closely with the RPF during the preparation of this report. Concerns and recommendations intended to minimize the potential impact of the proposed harvest on slope stability and erosion have been incorporated in the final THP by design. This study has been conducted following Department of Conservation, Division of Mines and Geology guidelines for Engineering Geologic reports for timber harvesting (DMG Note 45).

**SCOPE OF SERVICES**

Work performed during this investigation included:

1. Review of pertinent published and unpublished geologic reports relevant to the THP.
2. Geomorphic interpretation of one set of stereo aerial photographs (taken in 2000).
3. Geomorphic field reconnaissance of the THP area.
4. Discussions with Glen Edwards (RPF) and John Benbow
5. Data analysis and preparation of this report.

The following figures are attached to this report:

Figure 1: Regional Site Map
Figure 2; Geologic and Landslide Map
Figure 3: Sub-watershed Runoff Nodes for Hydrologic Analysis
Figure 4: Suspended sediment yield from Caspar Creek experimental watershed
Appendix A: Runoff calculations
Appendix B: Impact of harvesting on slope stability

**PROJECT DESCRIPTION**

The THP proposes a 185-acre harvest under Selection (104 acres), Alternative Prescription (32 acres) and Vineyard Conversion (49) silviculture. The proposed vineyard conversion is located along the gently sloping ridge tops. Outside of designated the WLPZ the RPF reports that in selection areas over 50% of the total stand (by basal area) will be retained and in the Alternative Prescription areas over 70% of the total stand will be retained. Current WLPZ rules will apply. Please refer to the THP for a more complete discussion of Silviculture prescriptions.

The THP proposes ground based tractor operations on slopes less than 40% with the exception of some tractor long lining on steeper slopes where feasible. Cable or helicopter operations are proposed on slopes greater than 50%. Silviculture, yarding and roading prescriptions have been modified in the interest of slope stability and hillslope erosion.

The THP proposes to use 0.6 miles of existing roads and will require the construction of 0.9 miles of new road. The new roads are necessary to access the ridge top for timber operations and future vineyard use. The majority of the new roads are located on moderate to gentle gradient slopes along ridge top and away from watercourses. A roughly 800 feet of new WLPZ road will be required to cross the valley bottom of Pocket Canyon. Existing roads are generally in relatively good condition but may benefit from some minor upgrades.

The THP also proposes to abandon 800 feet of existing road located on steep slopes adjacent to a Class III watercourse. Because of the steep gradient of this road, modest erosion is apparent. The abandonment of this road will help mitigate the potential impact of road related erosion and increased stream turbidity resulting from harvest operations.

## GEOLOGIC AND GEOMORPHIC SETTING

### GEOMORPHIC SETTING

The 185-acre THP is located gentle to steep ground on west side of Pocket Canyon. The property is bounded to the east by Highway 116 and to the west by the ridge crest. Several incised Class II and III watercourses drain the plan area (Figures 1 and 2). The topography of the THP area is fairly typical of the region, characterized by moderate to very steep terrain with slopes ranging from less than 10% along the broad, low gradient channel bottom of Pocket Canyon and gently sloping ridge tops, to greater than 75% along local steep streamside slopes. The hillslopes are slightly convex at high slope positions with rounded ridge tops. Slopes are typically straight and smooth and with the exception of small channel bank failures show little evidence of recent instability. Elevations range from 120 feet to 650 feet above sea level.

The plan area is drained by several intermittent to ephemeral, narrow and steep sided Class II and III watercourses. Most drainages are colluvial filled with a U-shaped cross-section. Outside of local small channel bank failures there is little evidence of channel instability. Substantial recent channel incision or aggradation was not observed.

A perennial Class II watercourse (Stream A) drains roughly 50 acres of the northeastern portion of the plan. This watercourse is fed by several small springs. Runoff from the watercourse drains into a small (1/2 acre) concrete lined pond is located at the mouth of the watercourse before entering Pocket Canyon Creek. Pocket Canyon is a broad, low gradient alluvial filled valley, draining an approximately 2560-acre watershed upstream of the plan area.

The central portion of the plan area is dissected by a northwest–southeast trending, narrow and steep sided intermittent Class II watercourse (Stream B). Field observations indicate that this channel is headcutting at a point about halfway up its length in the project area, with localized areas of channel and bank erosion. This watercourse drains an approximately 70-acre portion of the plan area and divides the property into two operational areas: the larger northern area has roaded access; the smaller southern area does not have roaded access from the property, although could be accessed from adjacent properties. A remnant of an old oxen road is found intermittently up the channel bottom of Stream B. This road was probably constructed around the turn of the century when the plan area was initially harvested.

The RPF reports the existing stand in the THP area to be a mixed forest of second growth even-age redwood and Douglas-fir of varying degrees of stocking, with tan oak hardwood understory. Generally, conifer is found along the valley bottoms and north facing slopes. Hardwood is more prevalent along the ridge tops and dryer south facing slopes. Please refer to the THP for a more complete discussion of the timber stands.

**Past Landuse**

Initial harvest entry on most of the private land probably occurred around the turn of the century when the largest trees along the bottom of the drainage were harvested. Most of the timber from this early logging was dragged down the axis of the larger watercourses to Pocket Canyon. Remnants of these oxen roads are locally preserved within lower portion of the Class II watercourses.

There is one residential home located at the base of the hillside in the northeastern portion of the property. Domestic water for this home is obtained from a small spring within Stream A, found upslope of the home. A small (1/2 acre) concrete lined pond is found at the mouth this watercourse. Very little sediment was observed deposited in the pond suggesting that erosion rates are relatively low. This is consistent with existing channel conditions observed in Stream A.

Adjacent properties within the 4.0 sq mile Pocket Canyon watershed upstream of Noel Heights have been historically used for agriculture, timber production, livestock and residential homes. Residential homes have increased within the watershed while commercial and agriculture use has diminished.

**Noel Heights water diversion**

The California Water Service Company (CWSC) operates a water diversion in Pocket Canyon at the downstream end of the subject property. This facility supplies domestic water to about 50 homes in the Noel Heights subdivision. Domestic water is pumped from a shallow well located immediately adjacent to Pock Gulch Creek. It is my understanding that the well is about 15 feet deep and that most of the water is obtained from underflow within the shallow alluvial sediments of Pocket Canyon. CWSC reports the system encounters increased turbidity problems during heavy storms and flooding. The potential impact of the proposed harvest on this water system was a focus of this study.

## REGIONAL GEOLOGIC SETTING

The rocks near the THP belong to Coastal Belt of the Triassic-Cretaceous aged Franciscan Assemblage (Huffman and Armstrong 1980)(Figure 2). This assemblage is described as pervasively shattered, massive greywacke-sandstone and thinly bedded shale with small amounts of greenstone, conglomerate and limestone. These rocks by nature are highly variable in composition and strength that controls, in part, the basin topography. The relative stability of slope underlain by Franciscan sedimentary rocks is often influenced by the abundance of mudstone, which is more susceptible to surficial weathering processes, and the frequency and orientation of joints and shears.

Bedrock is not well exposed in the THP area. Thinly bedded dark gray shale and sandstone was observed at a shallow depth along the left (west) channel bank of Pocket Canyon Creek adjacent to the bridge accessing the plan area. A small outcrop of fractured sandstone bedrock was also exposed in the channel bank of lower portion of Stream B, and locally in float along the ground surface throughout much of the plan.

Overlying the bedrock is a thin mantle of colluvium and soil. Mapped soils present in the plan area include Hugo-Josephine [HnG] Series. Colluvial deposits are found nearly everywhere across the hillside, and are typically thickest toward the axes of swales and drainages. Locally thick pockets of colluvium were encountered in a few of the steep swales indenting portions of the hillside. Colluvial soils consist primarily of well drained gravely sand and loams. Runoff is very rapid. Erosion Hazard Ratings (EHR) are Moderate to High.

The geologic and geomorphic development of the region has been controlled by Neogene uplift and deformation of the Coast Ranges associated with the movement between the North American Plate and Pacific Plate (plate tectonics). For the past 15 million years (mid -Miocene), the Pacific Plate has been slipping northwest with respect to the North American Plate (Atwater 1970). The Coast Range Mountains reflect the tectonic uplift associated with movement between these two plates.

The main trace of the active San Andreas Fault is located about 10 miles west and offshore. This segment of the San Andreas Fault last ruptured in 1906. This fault is capable of generating a Maximum Moment Magnitude 7.9 earthquake with a recurrence interval of roughly 210 years (Petersen et al., 1996). The active Rodgers Creek Fault is mapped about 11 miles northeast of the plan. This fault is capable of generating a Maximum Moment Magnitude 7.0 earthquake with a recurrence interval of 210 years (Petersen et al., 1996). High ground accelerations associated with fault rupture along either of these two fault systems is likely a contributing factor if not dominant for movement on deep-seated landslides. High ground accelerations can also be a contributing factor to the occurrence of shallow landslides.

## HYDROLOGIC CONDITIONS

This section evaluates the potential hydrologic changes associated with the proposed THP and vineyard conversion. Specifically, the analysis evaluates possible changes in:

- Annual water yield
- Dry season flows and dry year flows
- Peak flows

Research on watershed scale hydrologic processes conducted at Caspar Creek by the USDA Forest Service Redwood Sciences Laboratory (RSL) in cooperation with the Jackson Demonstration State Forest (JDSF) were used to help determine expected trends in water quantity and quality associated with the proposed THP and vineyard conversion. Watershed research at Caspar Creek is relevant because the hydrologic effects of conversion of forest stands to vineyards are comparable to the primary hydrologic effects of clearcut forest harvest.

The chief effects of clearcut timber harvest (excluding roads) on hydrologic processes are removal of existing vegetation and resultant changes in canopy interception and evapotranspiration. These changes are expected to increase water delivery to the soil, soil moisture, and runoff. Caspar Creek experimental results are particularly relevant to predicting the gross hydrologic effects of vegetation removal associated with timberland conversion to vineyard.

The proposed THP and vineyard development includes modifications of surface drainage pathways, collection of surface runoff from a large portion of the area in a drainage system, storage of a portion of the surface runoff for irrigation, and potential changes in soil hydrologic properties, including infiltration capacity, associated with vineyard site preparation and cultivation. Each of these potential effects will be addressed in this assessment.

The proximity and general similarity of the Caspar Creek watershed to the project site ensures that the experimental results at Caspar Creek are generally applicable. The Caspar Creek watershed, located in Mendocino County a few miles inland from the coast about halfway between the communities of Ft. Bragg and Mendocino, has generally similar climate, vegetation, soil and geologic conditions compared to the site near Guerneville. Annual rainfall at Caspar Creek and at the Project site is about 50 inches. There is a higher proportion of hardwood forest on the Project site compared to Caspar Creek. Drainage area of small Class II and Class III watersheds draining the Project site range from <5 to 70 acres. The North Fork Caspar Creek watershed is about 1,170 acres, and experimental sub-basins range in size from about 25 to 190 acres. These similarities in watershed size allow reasonable extrapolation of experimental results to the project site.

The majority of proposed conversion acreage is currently under forest cover in various stages of maturity. Removal of forest canopy, which includes components of redwood, Douglas fir, hardwoods and shrub understory, and replacement by vineyard, will affect interception and evapotranspiration processes.

**HYDROLOGIC EFFECTS**

The conversion of forest vegetation to vineyard will reduce the interception and evaporation of rainfall by forest canopy. Experimental data indicate that forest canopy intercepts and evaporates approximately 20% of storm precipitation in temperate coniferous forests (Dunne and Leopold 1978, pp. 87-88). Removal of the forest canopy therefore is expected to increase the quantity of precipitation reaching the ground surface, potentially causing ***increases*** in

- Infiltration of water to the soil and percolation to groundwater aquifers
- Summer streamflow
- Storm runoff.

These potential effects are discussed below in the context of regional scientific studies of redwood forest watershed hydrology.

Watershed experiments regarding the effects of harvesting redwood forests on streamflow and water quality have been conducted in the region for over 30 years at Caspar Creek (Ziemer, 1998a). As found in other watershed studies in the Pacific Northwest, increases in storm runoff during the first few rainstorms of the season may be large (Ziemer, 1981), however, "[t]hese first rains and consequent streamflow in the fall are usually small and geomorphically inconsequential in the Pacific Northwest" (Ziemer, 1998). These early winter increases in storm runoff have been attributed to reduced evapotranspiration from forest vegetation during the growing season, which causes a higher level of soil moisture and summer stream flow. In other words, following harvest, forest vegetation draws less water from the soil via its root system and more of the rain water that enters the soil during the wet season remains in the soil or moves by gravity into surface or sub-surface channels, or percolates to groundwater aquifers.

The change in evapotranspiration and/or canopy interception caused by forest harvest has been found to result in significant increases in both total annual runoff and minimum summer stream flow. At Caspar Creek, annual runoff increased an average of 15% for monitoring periods of about 10 years following harvest (Keppeler, 1998). These levels of flow increase were recorded in two different watershed experiments at gauge sites on Class I perennial streams with drainage areas > 1000 ac. Maximum annual increases were about 30%. Minimum mean daily summer flows increased an average of 148% following clearcut harvesting of about 50% of the watershed of North Fork Caspar Creek (Keppeler, 1998). The smallest increase was 75% and the largest was 287% over the period 1990-1997 (Table 1).

The Caspar Creek experiments also found increases in peak storm runoff following clear cut harvest of 50% of the North Fork watershed. Streams draining >95% clearcut harvested watersheds ranging in size from 25 to 67 ac in North Fork Caspar Creek were gauged for streamflow and compared to unlogged control watersheds (Ziemer, 1998). For storms with a recurrence interval of about 2 years, which generate peak runoff greater than about 0.11 cfs per acre of watershed area, there was a mean peak flow increase of 27% in the five clearcut tributaries. For the entire North Fork watershed (1,170 ac), the instantaneous peak flow increase for a 2-yr recurrence interval was 9% for an area that was 50% harvested. "As the size of the watershed increases and the proportion of the watershed logged decreases, the post-logging and pre-logging observations become more similar"(Ziemer, 1998), p.18).

Increases in total storm runoff were similar to those for peak runoff. Under the wettest antecedent conditions, total storm runoff volume increased 27% for clearcuts. Percentage increases were higher when antecedent wetness was lower. Annual storm runoff volume for all storms increased 60% in clearcut watersheds.

Statistical analyses of the runoff data that were designed to determine factors that significantly affect runoff rates found that only logged area and antecedent wetness were important. "No variables related to roads, skid trails, landings, firelines, burning, or herbicide application were found to improve the fit of the linear least squares model that includes logged area and its interaction with antecedent wetness" (Ziemer, 1998), p.19).

Lewis (1998) found that suspended sediment yield measured from the small watersheds studied in North Fork Caspar Creek increased on the order of 200% (a three-fold increase after harvest). Although the source of this increase in suspended sediment was not determined, it was suggested that a substantial portion was caused by accelerated channel or bank erosion associated with observed increases in stream flow. The likely magnitude of downstream effects of potential increases in suspended sediment associated with increased streamflow in small headwater streams is discussed later in this document.

## SUMMARY HYDROLOGIC EFFECTS

In summary, watershed experiments at Caspar Creek indicate substantial increases in annual water yield, summer minimum flows, and storm runoff following clearcut harvest in the North Fork Caspar Creek. In addition, suspended sediment yield for small watersheds (about 25 to 70 ac) increased substantially. Increased annual water yield is due largely to increased storm runoff which results from decreased canopy interception of rainfall and increased soil moisture; increased summer flows are significant, but represent a smaller proportion of the increased annual yield. Increased summer minimum flows result primarily from reduced growing-season evapotranspiration and higher soil moisture. The increasing trend in these parameters and the approximate magnitude of change is likely to be similar for conversion of forest to vineyard at the project site near Guerneville.

**Dry Season Flows and Annual Yield**

The preceding review and discussion of Caspar Creek experimental results leads to the conclusion that annual and seasonal stream flows are expected to increase as a result of the proposed conversion of timberland to vineyard.

Increased minimum flows in the dry season at Caspar Creek resulted in "increased habitat volumes, and...lengthened the flowing channel network along logged reaches (Keppeler, 1998), p. 43). Hence, it can be stated with relative certainty that the proposed project is not likely to reduce dry season flows, and is more likely to increase them. Furthermore, the Caspar Creek data indicate that this effect is likely to persist in relatively dry years.

As can be seen in Table 1, the post-logging period included the three years of lowest runoff (excluding 1977 and adjusting for the estimated increase in flow attributed to harvest effects), and a representative range of water yield compared to the pre-logging record. These data demonstrate that even in relatively dry years, it is expected that both minimum summer flows and annual yields will increase relative to existing conditions at the project site.

It should be noted that vineyard development and cultivation could also cause changes in soil infiltration capacity and flow paths that might affect rates of transmission of water from the soil surface into the soil (infiltration) and from the soil into bedrock aquifers (percolation). The conclusions drawn above do not explicitly account for such potential changes in soil hydrologic characteristics. These potential changes and their potential significance are discussed below.

*Table 1. North Fork Caspar Creek annual water yield 1963-1997 and minimum mean daily flow, ranked from lowest to highest annual yield. Figures in bold faces are post-logging data; water yields for these years were adjusted to the level predicted from pre-logging data after (Keppeler, 1998) Table 1. Minimum mean daily flows were not adjusted. Post-harvest flow increases are given in columns 3 and 5. No data were reported for the drought year 1977 in the source reference.*

| Water Year | Water Yield ($m^3$/ha/yr) | % Change Post-harvest Water Yield | Minimum Mean Daily Flow (L/s/$km^2$) | % Change Post-harvest Minimum Mean Daily Flow |
|---|---|---|---|---|
| **1991** | **1447** | **21** | **0.46** | **256** |
| **1994** | **2190** | **29** | **0.46** | **166** |
| **1992** | **2539** | **27** | **0.59** | **287** |
| 1981 | 2754 | | 0.28 | |
| 1976 | 3337 | | 0.36 | |
| 1987 | 3337 | | 0.23 | |
| 1964 | 3541 | | 0.17 | |
| 1988 | 3560 | | 0.26 | |
| 1985 | 3646 | | 0.23 | |
| **1990** | **3687** | **6** | **0.41** | **75** |
| 1972 | 3730 | | 0.34 | |
| 1968 | 3747 | | 0.22 | |
| 1979 | 4111 | | 0.64 | |
| 1989 | 4239 | | 0.46 | |
| 1966 | 4943 | | 0.22 | |
| 1963 | 5283 | | 0.72 | |
| 1986 | 6265 | | 0.49 | |
| 1980 | 6289 | | 0.54 | |
| 1984 | 6782 | | 0.28 | |
| **1996** | **6800** | **13** | **0.80** | **75** |
| **1997** | **6801** | **15** | **1.19** | **129** |
| 1978 | 6898 | | 0.43 | |
| 1967 | 6929 | | 0.40 | |
| 1970 | 6986 | | 0.16 | |
| 1965 | 7210 | | 0.29 | |
| 1971 | 7447 | | 0.46 | |
| **1993** | **7833** | **6** | **1.28** | **107** |
| 1975 | 7932 | | 0.55 | |
| 1973 | 8093 | | 0.37 | |
| 1969 | 8184 | | 0.26 | |
| **1995** | **9566** | **7** | **0.72** | **89** |
| 1982 | 9812 | | n.a. | |
| 1974 | 13054 | | 0.43 | |
| 1983 | 13919 | | 0.74 | |

**Potential Changes In Soil Hydrologic Characteristics**
Vineyard development may affect soil hydrologic characteristics through several mechanisms. These include potential changes in water infiltration rates and changes in topography and drainage that affect surface runoff paths. The following brief discussion of bedrock geology and soils at the Project site provides necessary background information.

As described elsewhere in this document, a single geologic formation underlies the Project site and a single soil type derived from the bedrock parent material mantles the slopes. Soils consist of the Hugo-Josephine complex (50-75%). This soil complex has relatively coarse-textured soils and moderately deep soils. Infiltration rates are 0.63 to 2.0 in/hr (USDA 1972), and no subsurface horizon limits infiltration rates. Precipitation rates in this area rarely exceed these infiltrations rates, consequently, surface saturation runoff is uncommon. Moreover, surface runoff that might develop locally on hillslopes would have substantial potential to be infiltrated to the soil prior to reaching a stream channel.

**Infiltration Processes and Rates:** Changes in infiltration rates associated with vineyard development at the project site could be either positive or negative. Decreased infiltration rates are generally expected when converting forested areas to agricultural fields owing to reduced root mass and soil compaction from agricultural practices. Infiltration rates for vineyard conditions are expected to decrease relative to pre-project conditions, however, a variety of agricultural practices and drainage designs will counteract the expected decrease. Vineyard cover crops will provide significant root mass and surface roughness to slow the flow of surface water, promoting infiltration. Moreover, if soil ripping is conducted in preparation for vineyard planting, infiltration rates might increase.

In addition, collection of surface water in "v-swales" in vineyard blocks will maintain low velocity of surface flows and promote infiltration. Where drainage is collected in v-swales, changes in topography and direction of runoff in the vineyard is expected to change surface flow paths relative to existing site conditions. Time of concentration is expected to be similar under post-project conditions because the v-swales tend to reduce slopes and lengthen flow paths, which compensates for increased flow velocity in drain pipes.

In summary, infiltration rates may decrease, but the changes are expected to be modest because compaction that may occur is counteracted by cover crops and lengthened flow paths that slow runoff velocity and promote infiltration. Consequently, peak flow increases are expected to be attributable to changes in vegetation cover and interception and evaporation of precipitation.

**Peak Flows**
As discussed above, removal of forest vegetation is expected to increase runoff rates, with some small potential increase owing to small decreases in infiltration rates to soil. Watershed experiments at Caspar Creek found that the rate of stream flow associated with a 2-year recurrence interval storm (probability of occurrence in any year = 50%) after clearcut harvest was about 27% greater than expected pre-harvest peak stream flow for small watersheds (about 25 to 70 ac). This portion of the analysis describes the method used to quantify the magnitude and location of expected peak flow increases at the project site.

**Peak Flow Runoff Calculations:** There are a variety of techniques that could be employed to quantify expected runoff rates. Owing to the small size of the drainage areas involved, modest data requirements, and relative simplicity of the technique, the "rational runoff method" was selected (Leopold and Dunne, 1978, pp. 298-305, Pacific Watershed Associates, 1994, Appendix A). This technique is often used in developing flow estimates for culvert sizing and other hydraulic design problems. The rational method utilizes a simple formula, Q = C I A, where instantaneous stream discharge, Q (cfs) is the product of a coefficient pertaining to the character of the watershed C, the precipitation rate I (in/hr), and the drainage area A (ac).

The coefficient C is determined from tables relating to land use characteristics of the watershed area (e.g. Dunne and Leopold, 1978, p.300). Relevant values of C for loam soils under cultivated and woodland conditions are 0.4 and 0.3 respectively. To estimate the effects of vineyard conversion on peak runoff, the rational method is evaluated under existing conditions and vineyard conditions. For the existing condition (pre-project), portions of the project area that are currently forested are evaluated for C=0.3. These areas are evaluated with C=0.4 for cultivated areas under the post-project scenario. Areas in the THP that may be harvested are assumed to have an average maximum canopy removal of 50%; the corresponding value of C used in these areas is 0.35. <u>Note that in some sub-areas of the THP (in particular, the Alternative Prescription area), significantly less than 50% of the canopy is expected to be removed, hence the calculations for these areas may exaggerate the harvest effect somewhat.</u> Forest cover is assumed to be 100% at present in all conversion areas. Acreage in the main sub-watersheds not on the Project site are small, and are assumed to have forest cover with C=0.4.

The precipitation rate (I) used is determined by the time of concentration of flow in the watershed and the magnitude and/or frequency of the design storm. The frequency (return period or recurrence interval) selected for evaluation is 2 years. Runoff increases for larger, less frequent rain storms are expected to diminish. For smaller, more frequent rain storms, percentage changes in runoff rates are expected to be larger, but of little geomorphic significance. The 1.5 year to 2 year recurrence interval flows are believed to be the most influential in determining channel form, and represent the magnitude of flows that do the most geomorphic work (Wolman and Miller 1960). Considering the geomorphic significance of the 2-year flow, and considering that the most significant effect of peak flow increases are hypothesized to be channel and bank erosion, the 2-year recurrence interval flow is particularly appropriate for this analysis.

As stated above, the Caspar Creek experiment found peak flow increases after logging of about 27% for 2-year recurrence flows. Using the rational runoff method, and holding all other factors equal, the conversion of woodland (C=0.3) to vineyard (C=0.4) would yield peak flow increases of 33% ([0.4-0.3]/0.3). Hence, using a 2-year design flow for the analysis would yield runoff predictions that are in general agreement with the Caspar Creek experimental data pertaining to changes in peak flow following vegetation removal.

The rational runoff technique requires determination of time of concentration; calculations for similar size watersheds in the region indicate that 15 minutes is a reasonable estimate. Hence, for calculations of peak instantaneous runoff (Appendix A), the duration of the storm to be evaluated is about 15 minutes. Estimates of precipitation for 15-minute storm duration can also be calculated using existing data (NOAA 1973). For the Project site, the estimated 2-year recurrence, 15-minute duration rainfall intensity was 0.42 in/hr. The equivalent rate for a one-hour period used in the rational runoff equation is 1.68 in/hr.

Drainage areas corresponding to different runoff nodes used for the runoff analysis were determined from Erosion Control and Mitigation Plan (ECMP) maps (Erickson Engineering, Inc., 2002) and from USGS topographic maps. The runoff nodes selected for analysis include subwatersheds in which concentrated vineyard runoff is anticipated and four of the larger subwatersheds as their channels exit the Project site (Figure 3). The range of drainage areas analyzed is < 1 ac to > 70 ac (Table 2).

The runoff analysis considers both short-term changes and long-term changes. Areas converted to vineyard are assumed to remain in that condition. Areas where timber harvest occurs are assumed to have C=0.35 for short term effects, and C=0.3 for long term effects reflecting hydrologic recovery and regrowth of forest vegetation to previous canopy and evapotranspiration conditions. The runoff analysis is conducted assuming that the reservoir functions as a detention basin and that the outflow rate is 50% of the inflow rate.

The limitations of estimating peak flows using any method, including the rational runoff method, are substantial. Hydrologic systems are complex, many of the variables are difficult to quantify, and models rarely produce precise results. The method employed for this analysis is expected to give peak flow estimates that are of the proper order of magnitude, but of undetermined accuracy. Of greater importance is generating an estimate of relative change for pre- and post-project conditions, and the technique used provides repeatable estimates of relative change using accepted methods and data inputs of a level of detail consistent with available data.

**Results: Predicted Pre- and Post-Project Peak Flow:** As shown in Table 2, short-term peak flow increases for the 2-yr, 15-minute design storm range from 19 to 36%. The highest short-term increases are generally for the smallest drainage areas that reflect only the vineyard conversion effects. Short-term increases are smaller on larger areas where substantial forest area is included. Long-term increases in runoff are markedly lower, ranging from 6 to 21%. For the three largest subwatersheds draining from the property (Streams A, B and C-Nodes 4, 10 and 9, respectively), the long term increases in peak runoff for the design storm are 12, 6 and 8% respectively.

*Table 2. Summary of results of the runoff analysis for individual runoff nodes (see Figure 4) for a 2-year, 15-minute duration rainstorm of 0.42 inches. Runoff coefficients (C) for existing forest and proposed vineyard are 0.3 and 0.4 respectively. Short-term change estimates effects of 50% canopy removal during harvest, with C=0.35. Long-term change estimates runoff after hydrologic recovery of forest stands with C=0.3; this is equivalent to an estimate of effects of conversion to vineyard only, with no other harvest.*

| Runoff Node | Area (ac) | Description | Pre-Project Flow (cfs) | Short-term Post-Project Flow (cfs) | Long-term Post-Project Flow (cfs) | % Change Short-term | % Change Long-term |
|---|---|---|---|---|---|---|---|
| 1 | 1.1 | D.L. 1.1 Vineyard Block B | 0.55 | 0.74 | -- | 35 | -- |
| 2 | 8.6 | Cl.III Drainage to Edge Property | 4.3 | 5.2 | 4.7 | 21 | 9 |
| 3 | 2.7 pre 2.9 post | D.L. 3.2 Vineyard Block B | 1.4 | 1.9 | -- | 36 | -- |
| 4 | 34 | Stream A to Existing Pond; Reservoir Outflow @ 50% of Inflow | 17 | 21 | 19 | 24 | 12 |
| 5 | 1.05 | D.L. 6.1 Vineyard Block A | 0.53 | 0.71 | -- | 34 | -- |
| 6 | 5.8 | Cl. III Drainage to Edge Property | 2.9 | 3.7 | 3.5 | 28 | 21 |
| 7 | 0.9 | D.L. 2.1 Vineyard Block B | 0.45 | 0.60 | -- | 33 | -- |
| 8 | 4.1 | Cl. III Drainage to Stream B | 2.1 | 2.5 | 2.3 | 19 | 10 |
| 9 | 15 | Stream C to Edge Property | 7.6 | 9.1 | 8.2 | 20 | 8 |
| 10 | 72 | Stream B to Edge Property | 36 | 44 | 38 | 22 | 6 |

### CONCLUSIONS

The most applicable research available strongly suggests that annual water yield and summer stream flows can be expected to increase owing to decreases in evapotranspiration processes associated with removal of forest vegetation. Soil and geologic conditions suggest that infiltration to the water table is not expected to decrease substantially. Peak flow increases are expected to occur in channels draining the Project site. Increased peak flows could result in slightly higher rates of stream bank erosion. This will be discussed in further detail in the following section. The proposed irrigation reservoir and existing 0.5 acre pond at the bottom of Stream A will function as sedimentation and runoff retention basin, further mitigating potential flow increases and water quality impacts.

## EROSIONAL PROCESSES

There are a variety of erosional processes acting in the watershed. The dominant processes include:

- **Landsliding**
- **Stream side erosion**
- **Road erosion**

### LANDSLIDING

Landslides on and adjacent to the THP area were identified from a review of published landslide maps, review of the 2000 color aerial photographs, and field reconnaissance of the THP area. Landslide classification and terminology based on (Bedrossian 1983; Crunden and Varnes 1996). A landslide map is included with this report as Figure 2.

**Shallow Landslide Processes**

Shallow landslides are classified as debris slides and debris flows and are typically characterized by rapid, shallow (generally less than 10 feet thick) downslope movement of surficial soil, colluvium, and weathered bedrock. Most natural shallow slides are triggered by elevated porewater pressures resulting from high intensity and/or long duration rainfall or from being under cut by stream bank erosion, however, many have also been reported to have occurred in other areas as a result of strong ground motions experienced during earthquakes. Most management related slides are associated with failure of the fill prism on older roads and skid trails. Silviculture related failures are, in comparison, much less frequent.

Very few shallow landslides were observed in the THP area and overall the ground does not appear to be highly prone to shallow landslide processes. The geomorphic expressions of swales and watercourses were typically subdued with smooth and straight sideslopes, indicative of a very low rate of slide activity. Very little debris was observed backed up behind trees within the axis of drainages. Such debris would be indicative of shallow slide activity within roughly the past 80 years. No road failures were observed, which in many watersheds is the leading source of management related sediment. The low rate of landsliding is attributed to the moderate gradient slopes that underlie most of the plan area and the expected competent nature of the underlying sandstone bedrock.

The following are specific observations of shallow landslides:

**Slide G1** is an historic debris slide that initiated on steep (75+%) side slopes above the head of a Class II watercourse. The slide averages 120 feet long, 100 feet wide 3 feet deep. An estimated 1000 cy of material was mobilized with most of the material retained on the hillside outside of the watercourse. Some material is backed up behind an old growth stump indicating the slide post dates the turn of the century harvest. However, the slide scar is also vegetated with second growth redwood, fir and oak. Presently the slide mass appears stable. Harvesting is not proposed on the slide and therefore is unlikely to have any impact on the slide.

**Site G2:** This is a steep amphitheatre located above the head of the Class II watercourse that drains the northern most portion of the plan area. The amphitheatre is indented by several narrow and steep gradient swales that were probably sculpted over time by repeated shallow landslide processes. Slope gradients within the amphitheatre are very steep, exceeding 80% in many locations. No recent landslides were observed, although remnants of several possible landslides were apparent. This is includes Slide G1, which is the largest and most recent failure observed.

Because of the steep slopes found in this area, there is a moderate potential for future landslides to occur regardless of landuse activities. The THP proposes to retain at least 50% of the total vegetative cover (by basal area), with harvest restricted to selected redwood stems removed from clonal groups. A significant reduction in root strength which could lead to slope instability is not expected in a light partial harvest of redwood, which resprout after cutting thereby maintaining a viable root network.

**Slide G3:** This is a 30 foot long, 30 foot wide and roughly 6 foot deep channel bank failure located on steep (80+%) banks along the Class II watercourse (Stream B) draining the central portion of the plan. The slide block down dropped several feet probably due to the toe of the slope being undercut by stream bank erosion. There is one straight fir tree in the displaced slide mass. In general, the steep slopes along the Class II watercourse are adequately protected by standard EWLPZ rules which will limit the harvest to a light selection. Nonetheless, harvesting is not proposed on this slide and therefore should have little impact on its stability.

**Deep Seated Landslides**

Deep-seated landslides, unlike shallow debris slides, are characterized by the relatively slow and/or infrequent movement of a largely intact slide mass above a comparatively deep failure plane. The slide plane typically extends below the colluvial layer into the underlying and more competent bedrock. Many deep-seated translational landslides exceed 10-acres in area, and have a failure plane extending 50' or more into bedrock. Failure surfaces can be planar (producing translational movement) or curved (producing rotational movement). Translational slides are commonly structurally controlled by surfaces of weakness within bedrock such as bedding planes, joints, and faults.

**Slide G4:** Huffman and Armstrong (1980) mapped a roughly 35 acre questionable deep-seated landslide underlying the eastern portion of the plan. However, our inspection of the 2000 aerial photographs did not reveal any evidence for this existence of this feature. Moreover, outside of a subtle midslope bench and weak spring flow in tributary channels of Stream A, there was no evidence observed during our field reconnaissance to confirm the existence this slide. No evidence of any other deep-seated landslide was observed within the plan area and it is our opinion that the potential for deep-seated landsliding in the THP area is very low.

**Impact of the Proposed Harvest on Landslide Processes**

Timber harvesting (timber removal alone) can potentially affect hillslope stability by reducing root reinforcement in shallow soils as the roots of harvested trees decay and the temporary increase in water input and soil moisture because of reduced evapotranspiration and rainfall interception. Refer to Appendix B for a more complete discussion of the impact of harvesting on landslide processes.

In our opinion, the likelihood of a significant increase in sediment production from increased landsliding resulting from the proposed harvest is low. The aerial photographs and field reconnaissance revealed very few shallow landslides within the THP area, even though the area has experienced stressing storms over the past several years. Moreover, there is little evidence to suggest a significant increase in shallow landslides following the turn of the century harvest.

The THP proposes a light partial harvest in most areas of the plan, removing on average less than 50% of the total vegetation. A significant reduction in root strength or evapotranspiration which could lead to shallow instability is not expected where partial harvest is employed and where a large component of the stand is redwood and hardwood which resprout vigorously after cutting thereby maintaining a viable root network (see Appendix B).

In the vineyard conversion and Rehabilitation of Understocked areas, the THP proposes to remove most of the timber. However, these areas are located on stable gentle sloping ridge tops (less than 40%). The impact of the harvest on landsliding in this area is expected to be negligible.

Although few landslides were observed, the most sensitive portion of the plan area are the steep streamside slopes of all watercourses and Area G1 located in the northern portion of the plan area. Class II watercourses are adequately protected by standard WLPZ rules which will retain on average 70% of the canopy cover (the RPF reports that less than 30% of the total vegetation (by basal area) will be removed). Along the Class III watercourses and Area G1, the proposed selection harvest will retain over 50% of the total vegetation by basal area. Harvesting in that area will be restricted to redwoods in groups. Moreover, any impact is likely to be short lived diminishing significantly as vegetation become re-established. Because the harvest plan calls for cable or helicopter logging on most slopes, undercutting of the toe of the slope by grading will not occur.

## STREAM BANK EROSION

Stream bank erosion includes diffuse surface erosion and incision of the channel bed and lateral bank erosion caused by stream flow and concentrated runoff. Bank erosion is much more difficult to quantify at a watershed scale than landsliding because the erosion features are generally smaller, more widely dispersed, and difficult or impossible to identify in forested areas using aerial photographs.

There are 4400 feet of Class II and 4100 feet of Class III watercourses within the plan area. Watercourses are generally alluvial/colluvial filled with U-shaped cross-sections. Class III watercourses have steeper channel profiles (~ 20% to 50%) compared to Class II watercourses (~5% to 30%). The active channel is typically relatively shallow, entrenched only a few inches in colluvial and alluvial material in Class III channels and most Class II channels. The lower half of Stream B is incised as much as 8 feet.

Channel conditions were observed in the field in March 2002 following periods of high rainfall and runoff in the preceding months of November, December and January. Flow levels recorded at stream gauging stations in the region were near the 1.5- to 2-year recurrence interval for some of these rainstorms, suggesting that flow levels at the project site could be expected to be near that of the design storm for this analysis. Field observations focused on channel bed and bank material, evidence of channel and bank erosion, and flow width and depth indicated by recent high water marks.

A possible old oxen trail that extends intermittently up the axis of Stream B is moderately well preserved suggesting significant stream bank erosion has not occurred in the upper half of the watershed since the turn of the century. Very few areas of recent bank erosion or bank instability were observed even though the channel has experienced several large flood events in the past 10 years. Very little bank or channel erosion was observed in Stream A, which drains raining a 50 acre area, discharges into a concrete lined pool at the base of the hillside. There is little evidence of significant deposition at the mouth of that stream where it enters into the pond. Overall, all channels inspected in the THP generally appear relatively stable with little evidence of significant bank erosion or channel deposition, except some areas in the lower portion of Stream B. Evidence of downstream transport of sediment was limited in Class III channels. Infrequent, small deposits of sand and fine gravel were observed locally.

Although the volume of sediment production from streamside erosion does not appear to be great, our field observations indicate that stream bank erosion is likely the dominant erosional processes acting within the THP area. No evidence of surface erosion outside of the stream channel was observed during our field reconnaissance. Similar results have been found in other watersheds (Harden et al. 1978; Kelsey et al. 1981; Trihey & Associates 1996; Trihey & Associates 1997).

**Impact of harvest and vineyard conversion on hillslope and stream bank erosion**
The proposed THP and vineyard conversion could result in slightly higher peak storm flows, which in turn could lead to slightly higher rates of stream bank and channel erosion in the colluvial filled watercourses. This conclusion is based, in part, on work by Lewis (1988) in Casper Creek that suggested that channel erosion could be a significant component of observed increases (200% or more in the worst case) in suspended sediment yield resulting following clearcuts in small watersheds. The Caspar Creek study (Lewis 1998), however, did not demonstrate that increases in suspended sediment yield from channel erosion in headwater streams (Class II and Class III channels) resulted in increased suspended sediment loads in downstream Class I channels. Furthermore, the change in sediment yield following harvest in the smallest watersheds (<70 ac) was negligible.

Three monitoring stations on the mainstem of the North Fork Caspar Creek showed an increase of 2% at one station, and decreases of 2% and 17% at two other stations. These data document that there was little or no change in suspended sediment yield in Class I channels downstream, despite large increases in tributary channels. This can be explained by the fact that erosion rates in the headwater channels are very low, and that when those rates are increased by a factor of two or more, the absolute erosion rate remains small relative to erosion rates in the watershed and mainstem channel as a whole. The overall increase in suspended sediment yield for the North Fork Caspar Creek is attributed to a single landslide that occurred near the end of the study period (Lewis 1998), and not to increased erosion rates in headwater channels.

Based on the Caspar Creek data, it is reasonable to conclude that a slight increase in channel bank erosion may occur as a result of the project but that the expected increase is unlikely to be significant impact on downstream aquatic habitat and quality. This is also supported by our field observations which found little recent channel bank erosion even though the watershed has experienced several large magnitude storms in recent years. The impact of the proposed harvest would be likely greatest on the smaller watercourses. The impact to Pocket Canyon will likely be imperceptible because of the expected small increase in erosion and the relative small size of the project area. The basis for this conclusion is discussed below.

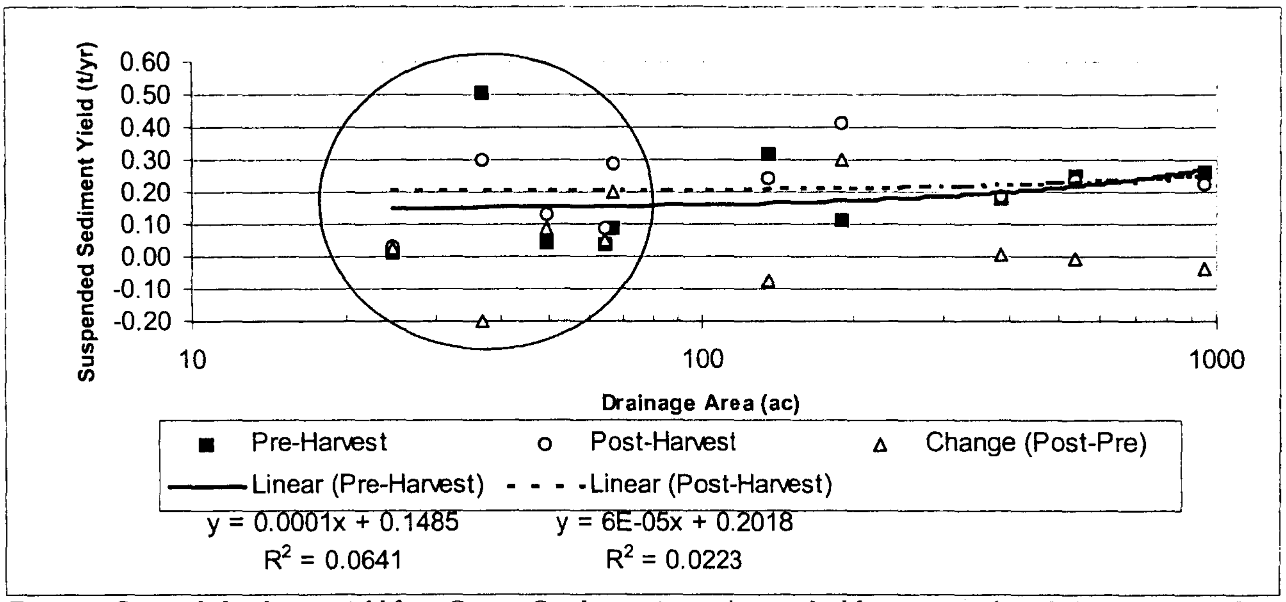


*Figure 4. Suspended sediment yield from Caspar Creek experimental watershed for watersheds with drainage areas less than 1000 acres (sites ARF, BAN, CAR, DOL, EAG, FLY, GIB, JOH, KJE and LAN). The circled area locates Caspar Creek sites with the smallest drainage areas (<70 ac), which most closely correspond to drainage areas for the Project site. The trendlines serve to illustrate the tendency for pre- and post-harvest sediment yields to converge at sites with larger drainage area.*

As shown in Figure 4 above, the Caspar Creek experiment found increases in suspended sediment yield for some small watersheds following clearcut timber harvests and decreases in others. There are different ways to analyze and interpret these data. The author of the study from which the data are drawn presents results in both in terms of sediment yield per unit watershed area (i.e. t/ac/yr) and percent change post-harvest. For the five smallest watersheds < 70 ac (BAN, KJE, GIB, CAR and EAG), which are most representative of the Project site, the average increase comparing each site before and after harvest was about 140%. In contrast, in the larger Class I channels downstream, the average change is a *decrease* of about 4%. This apparent disparity in the data is explained by the fact that the larger percentage increases affect very small sediment yields, hence large percentage increases in small yields do not amount to large increases in sediment yield in the larger watershed downstream. Given the natural variability of sediment yield data, the decrease in yield in larger channels is not the significant issue; rather, it is the lack of perceptible increases despite large percentage increases in smaller tributary watersheds. Also, given the variability of these processes over time and space, additional perspective may be gained by considering the average sediment yields before and after harvest for the five smaller sites most representative of drainage areas on the Project site. A net increase in yield of 0.03 t/ac/yr (about 20%) was observed following timber harvest (0.14 t/ac/yr pre-harvest to 0.17 t/ac/yr post-harvest). Hence, despite evidence of large percentage increases in sediment yield in small drainages, the harvest effect on sediment yield in larger streams downstream in the same watershed (North Fork Caspar Creek) is not substantial. Any increase from the harvest would be short lived, diminishing as vegetation became re-established.

The magnitude of erosion from the project site, regardless of potential effects of timber harvest and vineyard development, can be assessed by reference to the sediment yield data for Caspar Creek discussed above and from other regional sediment yield studies. In the Caspar Creek data may be reasonably representative of the magnitude of sediment yield that might be expected from the larger tributaries draining the project site (Streams A, B and C; 34 ac, 72 ac and 15 ac respectively). Hence, the approximate suspended sediment yield from the Project site following development from these three main drainages might be about 20 t/yr assuming an average annual yield of 0.17 t/ac.

The average suspended sediment yield of 20 t/yr may be compared to other regional yields for larger areas to assess the relative contribution of erosion from the Project site to the Pocket Canyon watershed. A review of regional sediment yield studies for larger river basins in the northern California Coast Range was produced by Kramer et al. (2001). An estimate of "background" or "natural" sediment yields can be derived from their data by taking the difference between total sediment yield and the sediment attributed to forest harvest and roads. Watersheds with the geology and climate most comparable to Pocket Canyon are the Noyo River, the Navarro River and the Garcia River. The estimated background yields for these watersheds were 340, 1100, and 150 t/sq.mi./yr, respectively. Given the drainage area of Pocket Canyon at the Noel Heights water well of 4.0 sq. mi., and the three estimates of background sediment yield per unit watershed area, the range of estimated yields for Pocket Canyon is 600 to 4,400 t/yr. This suggests that the Project site contributes about 3% of the sediment yield for the watershed above the Noel Heights water diversion

An alternative calculation of the contribution of sediment yield from the Project site to the Pocket Canyon watershed assumes that sediment yield is proportional to drainage area. Hence, if the entire project area of 185 ac (about 0.29 sq. mi.) is compared to the Pocket Canyon watershed area of 4.0 sq. mi., then the Project site contribution is about 7.3% (0.29/4.0) of the total of the watershed (See Figure 1).

In summary, the review of the Caspar Creek experiment and extrapolation of regional data to Pocket Canyon suggests that the Project site contributes perhaps 3% to 7% of the sediment delivered to stream channel from the area upstream of the Noel Heights water diversion. Increases in sediment yield from the Project site are expected to be very small based on data from Caspar Creek, the limited extent of timber harvest proposed, and erosion control measures to be implemented for the vineyard conversion area.

Erosion control measures specified in the ECMP (Erosion Control & Mitigation Plan, Erickson Engineering, Inc.) provide protection for bed and banks at concentrated discharge points, and silt fencing and other surface erosion control measures along the vineyard boundary where flow might concentrate. These measures will provide significant mitigation of potential bed and bank erosion associated with potential peak flow increases.

**ROAD EROSION**

The THP proposes to utilize 8100 feet of new and existing roads in the project area. This includes 4100 feet of existing roads in the THP area that were constructed for residential use or to provide general access to the property. With the exception of a roughly 1200 foot long segment of road in adjacent to Stream A, these old roads show little visible signs of significant erosion or instability but could benefit from upgrades proposed in the THP. Sediment yield off of the existing ridge top roads is expected to be negligible.

A roughly 1200 foot long existing road extends up the south side of Stream A and provides access to water tanks (domestic water supply) in the drainage and access to the ridge top. Although this road is steep and is presently not well drained, little erosion was apparent. The proposed abandonment of the upper 700 feet of this road and upgrades to lower segment of road (permanent drainage structures and road rock), will reduce the small amount of erosion and sedimentation that currently occurs as a result of this road. There is one existing stream crossing on Stream A just above the rock-lined pond. No treatment is warranted at this site.

The THP proposes about 4600 feet miles of new road. About 3500 feet of the new road is proposed on moderate gradient slopes along the ridge top and away from watercourses. Sediment yield off of the ridge top road is expected to be negligible provided the road is properly drained.

The THP also proposes an 1100 long segment of road that branches off of Highway 116, crosses Pocket Canyon and then climbs at a moderate gradient to reach an existing road. The entire road will be rocked and a bridge crossing proposed over Pocket Canyon. A small amount of post construction erosion may occur but is not considered to be significant.

During our field inspection of the existing and proposed network we did not identify any areas of significant geologic concern that would warrant additional erosion control measures outside of what is proposed in the THP, the Erosion Control Plan and required by current Forest Practice Rules. It is our opinion that the amount of erosion expected off of the road network will be small and should have a negligible impact on the water quality of Pocket Canyon. A more quantitative analysis of sediment yield off of the road system is judged not to be warranted.

## DISCUSSION and CONCLUSION

The THP proposes a 185-acre cable and tractor harvest on the gentle to steep ground on the west side of Pocket Canyon. Included is the conversion of 49 acres of gently to moderately sloping ridgetop ground to vineyard. Outside of the vineyard conversion, the proposed harvest is expected to retain 50% to 70% of the total vegetation (by basal area). The THP proposes to use 0.6 miles of existing roads and will require the construction of 0.9 miles of new road to gain suitable access to the ridge top. The THP also proposes to abandon 800 feet of existing road located on steep slopes adjacent to a Class III watercourse. Existing roads are generally in relatively good condition but may benefit from some minor upgrades. Silviculture, yarding and roading prescriptions have been modified in the interest of slope stability and hillslope erosion.

The most applicable research available strongly suggests that annual water yield and summer stream flows resulting from the proposed project can be expected to <u>increase</u> owing to decreases in evapotranspiration processes associated with removal of forest vegetation. Soil and geologic conditions suggest that infiltration to the water table is not expected to decrease substantially. Peak flow is expected to increase in channels draining the Project site. This increase is not expected to have a substantial impact on the channels, however. The proposed irrigation reservoir and existing 0.5 acre pond at the bottom of Stream A will function as sedimentation and runoff retention basin, further mitigating potential flow increases and water quality impacts.

A variety of processes are responsible for sediment production within project area. These include landslides, stream bank and channel erosion, and erosion of the road surface.

Very few landslides were observed in the THP area and overall the ground does not appear to be highly prone to landslide processes, primarily because slopes are not very steep. It is our opinion that the potential for significant sediment input from shallow or deep-seated landslides originating in the THP area is very low.

Sediment production from streamside erosion is likely the dominant erosional process acting within the project area. Sediment yield from streamside erosion is considered to be low, however. The proposed THP and vineyard conversion could result in slightly higher peak storm flows, which in turn could lead to slightly higher rates of stream bank and channel erosion in the colluvial filled watercourses. However, increases in sediment yield from the Project site are expected to be very small, in part due to the limited extent of timber harvest proposed and erosion control measures to be implemented for the vineyard conversion area.

Erosion control measures specified in the ECMP (Erosion Control & Mitigation Plan, Erickson Engineering, Inc.) provide protection for bed and banks at concentrated discharge points, and silt fencing and other surface erosion control measures along the vineyard boundary where flow might concentrate. These measures will provide significant mitigation of potential bed and bank erosion associated with potential peak flow increases.

Expected sediment production from the existing and proposed road network is judged to be small, provided the roads are adequately drained. The road network is located mainly on the ridge top and on moderate gradient sideslopes. With the exception of a roughly 1200 foot long segment of road adjacent to Stream A, these old roads show little visible signs of significant erosion or instability. Because the majority of roads are located away from watercourses, any erosion that does occur is unlikely to be delivered to a watercourse. Proposed road improvements outlined in the THP which include rocking of all roads and the abandonment the existing road adjacent to Stream A will likely reduce sediment relative to existing conditions. It is our opinion that the amount of erosion expected off of the road network will be small and should have a negligible impact on the water quality of Pocket Canyon.

Overall, it is estimated that the proposed project area contributes less than 7% of the total sediment to the Pocket Canyon watershed upstream of the project area. As previously discussed, any increase in sediment coming off of the project area is expected to be very small. Any increase will most likely be imperceptible within Pocket Canyon.

Future erosion from the THP area is likely to be small in comparison to existing erosion from other properties in the watershed, including the residential roads accessing the Noel Heights subdivision. Most of that road was poorly drained and is located immediately adjacent to a watercourse. The drainage provision on that road is considerably lower than what is proposed in the THP area and required under Forest Practice Rules.

A significant and unacceptable impact to the Noel Heights water intake, located on the downstream side of the Project area, is defined in this report to be an increase in turbidity above background levels resulting from the proposed Project that would result in the shutdown of the water system and depletion of storage reserves. It is unlikely that measurable changes in water quality or sedimentation would occur in Pocket Canyon, in part because of low erosion rates expected from the Project site and in part because of the minimal influence of the Project relative to influences in the 4.0 square mile drainage area above the public water supply near Noel Heights.

It is our opinion that the potential for a significant impact to the Noel Heights waters system from increased turbidity will be negligible. For the reasons discussed earlier in this report, any increase in turbidity or sediment input resulting from a limited and low intensity harvest is expected to be small. Moreover, any increase stemming from the plan area would be substantially diminished once it reaches Pocket Canyon Creek, which drains a substantially larger area than the THP. The inherent variability of storms capable of generating elevated turbidity levels will likely have a much greater impact than any increase associated with the proposed harvest. Furthermore, storms capable of generating prolonged turbidity levels occurs infrequently.

# RECOMMENDATIONS

By design, the THP has been modified based on the results of this study to avoid or limit the harvest on areas judge to be highly sensitive to management activities. The following are additional specific recommendations that should be incorporated into the final THP.

## SPECIFIC RECOMMENDATIONS

**Slide G1: Historic Debris slide**

1. Harvesting shall be excluded on and within 15 feet of this slide. The RPF shall flag this area out.

**Area G2: Debris slide amphitheatre**

1. The THP shall retain at least 50% of the total vegetative cover (by basal area) within this area.
2. The harvest shall also restricted to selected redwood stems removed from clonal groups.
3. The RPF shall mark this area to ensure these recommendations are properly implemented.

**Slide G3: Channel Bank failure**

1. Harvesting shall be excluded on and within 15 feet of this slide. The RPF shall flag this area out.

**Abandoned haul roads**

1. Designated haul roads shall be abandoned per the THP (see Section II).
2. All watercourse crossings shall be abandoned per Title 14 CCR 923.3(d) which states as follows : *"When watercourse crossings, other drainage structures, and associated fills are removed the following standards will apply : (1) Fills shall be excavated to form a channel which is as close as feasible to the natural watercourse grade and orientation and is wider than the natural channel. (2) The excavated material and any resulting cut bank shall be sloped back from the channel and stabilized by seeding, mulching, rock armoring, or other suitable treatment."*

## GENERAL RECOMMENDATIONS

**THP (GTE Associates) and Erosion Control & Mitigation Plan (Erickson Engineering, Inc.)**

1. Recommendations outlined in the two above referenced documents shall be properly implemented and maintained.

**Road Drainage**

1. The road surface shall be drained per standard Forest Practice Rules. On roads with grades less than 10% the road may be drained by outsloping and rolling dips. On road grades greater than 10% outsloping and rolling dips can be ineffective and therefore large waterbars may need to be installed.
2. The landowners shall be responsible for maintaining the erosion protection.
3. Upgrading and maintaining roads in accordance with current Forest Practice Rules will have the greatest impact on minimizing future erosion. The landowners should be familiar with concepts of erosion control and road maintenance outlined in the Mendocino County RCD, Handbook of Forest and Ranch Roads (PWA 1994).
4. All permanent roads shall be rocked with a minimum of 4" of base rock

**Stream Channel and Bank Erosion**

1. Following development of vineyard drainage facilities, channel conditions downstream of points where concentrated runoff is discharged should be observed. Following runoff-producing rainfall events in the first few years after vineyard development, stream channels should be inspected for evidence of erosion.
2. Appropriate supplemental erosion control measures should be implemented should substantial erosion sources be identified during the channel inspections described above.

**Other**

1. If any unexpected variations in soil conditions, or any unanticipated geologic conditions are encountered during construction, or if the proposed project will differ from that discussed or illustrated in this report, we require that we be notified so supplemental recommendations can be given.